

Introduction to Engineering Seismology
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Module No # 04
Lecture No # 17
Concept of Earthquake Quantification – Magnitude

So vanakkam so we will continue our class on so concept of earthquake quantification ok. So this basically we discussed that the earthquake can be quantified 2 ways one is that intensity and the other one is magnitude. So if we recall the first part of the intensity discussion so we have discussed that the people are written a magnitude and then also they written a so moment magnitude. And also I told you that so the magnitude can be different for different wave type which is used.

So when this magnitude concept comes in to picture ok. So how, the magnitude quantification has been started the engineering seismology. And what we practice today is we are going to discuss in this class and followed by there is a so the energy released from the different earthquake and what type of magnitude how it is there all those things we have to discuss that in today's class.

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Magnitude

- ❖ If the sizes of earthquakes are to be compared worldwide, a measure is needed that **does not depend (as does intensity) on the density of population and type of construction.**
- ❖ A strictly quantitative scale of size that can be applied to earthquakes in both inhabited and uninhabited regions was originated in **1931 by K. Wadati in Japan and developed by the late Professor Charles Richter in 1935 in California.**
- ❖ The scheme is to use the wave amplitudes measured by a seismograph.
- ❖ This idea is similar to that of astronomers who grade the size of stars using a **stellar magnitude** scale based on the relative brightness seen through a telescope.

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So the magnitude is basically the size of the earthquake that are to be compared worldwide to measure is needed that does not depend ok as does intensity on the density of the population and

type of construction. So as we discussed that the intensity scale for example the intensity earthquake occurred in the forest region there is no people, there is no construction then the intensity scale is nowhere reported or it is 0 ok.

But actually the earthquakes are occurred. So such intensity is actually the function of number of people living there and number of houses and construction type in the region. So this kind of things are biased. For example, the same earthquake occurring on Bangalore, the same earthquake occurring on Mysore, the same earthquake occurring somewhere north Karnataka reports village ok.

So we will have the different intensity because of the population and type of construction practiced in these places. Even, though the earthquake may release a same amount of the energy and the same magnitude. So these have been identified by the scientist and then they started thinking how to overcome this. A strictly quantitative scale of size that can be applied to earthquake in both inhabited and as well as the so uninhabited regions.

So, habited and inhabited regions so that it can be commonly give the same magnitude of value. So it was realized by the Wadati in Japan and then they developed by the late professor Charles Richter in 1935 in California ok. So the Charles Richter first thought about this and come up with the idea called magnitude. So this scheme is to use the wave amplitudes to measure in the seismograph ok. So we know that seismogram can record P wave and S wave and R wave depends upon the seismogram.

So we try to use it and try to give you the magnitude. The idea is come from that, generally the astronomers what they do actually? They guess a size of a star ok by looking at its brightness ok. So how bright is? So the brighter star is assumed to be a bigger in scale ok. So that is what they did the similar kind of concept has been extended here to quantify the earthquake magnitude ok, the earthquake size in terms of magnitude.

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- Related to Energy Release.
- Quantitative measurement of the amount of energy released by an earthquake
- Depends on the size of the fault that breaks
- Determined from seismic records

Richter magnitude

- The magnitude of a local earthquake is the logarithm to base 10 of the maximum seismic-wave amplitude (in thousandths of a millimeter) recorded on a standard seismograph at a distance of 100 kilometers from the epicenter.
- Because earthquake sources are located at all distances from seismographic stations, Richter further developed a method of making allowance for this attenuation with epicentral distance when calculating the Richter magnitude of an earthquake.
- An uncomplicated earthquake record clearly shows a P wave, an S wave, and a train of Rayleigh waves. (The seismogram shows only the vertical component of the ground motion.) Now, if Richter's procedure for determining local magnitude were followed, we would measure the amplitude of the largest of the three waves and then make some adjustment for epicentral distance and the magnification of the seismograph.

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So these basically relate energy released by the earthquake because the wave form is a function of how much energy released ok. So the quantitative measurement amount of energy released by an earthquake will be reflected in the wave form what you see. It depends upon the size of the fault that breaks. So, as you know that the bigger fault breaks you will get a higher amplitude waves. So then they determined from the seismic record. So that means if you want to estimate a magnitude you need to have the recorded earthquake data.

For intensity you do not need to have any such kind of recorded. You need to have the damage observation physically by going to the sight or by getting the photos and try to understand. So these are all the 2 ways you can estimate a intensity. So the Richter magnitude basically a magnitude of the local earthquake is the logarithmic to base 10 of the maximum seismic wave amplitude in thousandth millimeter recorded on a standard seismogram at a distance of 100 kilometer from the epicenter.

So here you should note that it should be maximum seismic wave amplitude ok in thousands of millimeter recorded at a standard seismogram and distance of 100 kilometer from the epicenter. So beyond this kind of distance you need to apply some kind of correction. Because the earthquakes sources are located at all the distances from seismogram station, Richter further developed method to making allowance for the basically attenuation of the wave with epicentral distance when calculation the Richter magnitude.

So uncomplicated earthquake record clearly shows the P wave and S wave and a train up of Rayleigh wave which is surfaced where the seismogram shows only the vertical component of the ground motion it can only show a one component. So now the Richter procedure; for determining the local magnitude were followed. We would measure the amplitude of the largest of the 3 wave then make some adjustment to the epicentral distance and then the magnification of the seismogram then you will get a magnitude.

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- Standard Wood-Anderson Seismograph has a natural period of 0.8 seconds
- A critical damping ratio of 0.8
- An earthquake amplification factor of 2800
- It amplifies waves with periods between approximately 0.5 and 1.5 seconds i.e. wavelengths of 500 m to 2 km- these waves are of particular interest for earthquake engineering due to their potential to cause damage

$$M_L = \log_{10} A(mm) - \log(A_0)$$

- Where A is Seismic wave amplitude in microns and A₀ is a calibration factor depends on distance
- Richter scale was calibrated assuming that magnitude M_L =3 corresponds to an earthquake at a distance of 100 km distance with maximum amplitude of A=1.0 mm. indeed, log A₀ =-3 for a distance D=100 km

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So that magnitude will be the Richter magnitude. So what was the Richter was used when he was arrived the magnitude basically used standard wood Anderson seismogram which was a so oldest seismogram which was developed. And then has been a natural period of so many second. These are all the very important the critical damping of the instrument is so much ok. The earthquake amplification factor is so much. How much the data is amplifies.

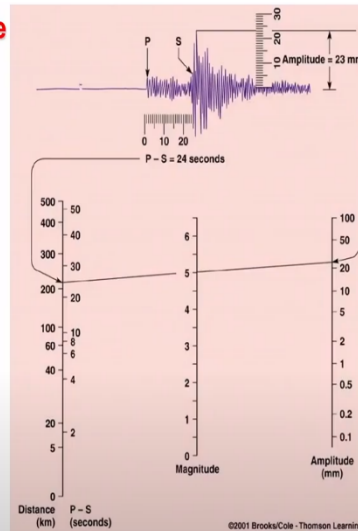
So it amplifies waves with period between he point 5 to 1.5 seconds the wavelength of 500 m to 2 km this waves are particular interest of the earthquake engineering due to their potential. So the ML is the function of log 10 A is the amplitude and then the A naught is a basically the calibration factor depends upon the distance ok. So base using this you can estimate what is the ML. The Richter scale was calibrated assuming that the magnitude of ML 3 correspond to the earthquake distance of 100 kilometer distance.

So with the maximum amplitude of mm indeed $\log A_0 = -3$ for a distance D equal to this one. So this is the wave where the bench marking has been done at initially by the Richter which has been used for arrive the Richter magnitude.

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Richter's Local Magnitude

Right side diagram (nomogram) demonstrates how to use Richter's original method to measure a seismogram for a magnitude estimate. After you measure the wave amplitude you have to take its logarithm and scale it according to the distance of the seismometer from the earthquake, estimated by the S-P time difference. The S-P time, in seconds, makes Δt . The equation behind this nomogram, used by Richter in Southern California, is:



$$M_L = \log_{10} A(\text{mm}) + 3 \log_{10} [8 \Delta t (\text{sec})] - 2.93$$

So how it works? You can see a typical waveform record of the particular earthquake okay. So this earthquake you can see ok. So you can basically so you can see the P wave and the S wave then followed by surface wave. So this particular location the P and S waves are very predominant when compare to the surface wave. So as per the Richter definition he says that maximum of this 3 amplitude you can see that maximum can be obtained from this particular place.

So you know what is the amplitude in the mm scale? So which; is basically this value ok since you know the P wave and S wave arrival so you can also get what is the time difference. This time difference as you told you that it gives you the how the earthquake epicenter is from your station record in terms of degree and you can multiply with the 110 kilometer per degree you can get a what is the distance.

You can see the P and S wave difference and their distance this ok. So by connecting these 2 you can connect this you will get a magnitude or you can use the equation where you get a magnitude. So finally based on this kind of explanation so the magnitude M_L can be estimated

using this functional form ok. So, where the amplitude of earthquake goes and the time difference and the distances also accounted with some kind of practice.

So you can see that it is in the log of 10. So the log of 10 means that the earthquake magnitude of 6 ok is 10 times larger than the earthquake magnitude of 5 ok. So the earthquake magnitude of 6.2 is actually 20 times larger than the magnitude of earthquake magnitude of sorry earthquake magnitude of 6.2 is actually 2 times larger than the magnitude of earthquake 6 ok. So 0.2 it is but 2 times so the 7 means it is 10 times. So that is what the log base 10 here indicates.

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Comparison to the Richter Scale and MMI

Earthquake	Death Toll	Richter Magnitude	Mercalli intensity
Tangshan earthquake (1976)	250,000	7.8-8.2	XI ^[4]
Loma Prieta earthquake (1989)	63	6.9	IX ^[4]
Kobe earthquake (1995)	6,434	6.8	X-XI ^[4]
Haiti earthquake (2010)	316,000	7.0	X
Christchurch earthquake (2011)	166 (final count expected to be over 180)	6.3	XI
Tōhoku earthquake (2011)	5400 confirmed, 8000 reported missing (final count expected to be over 10000). Totals include tsunami.	9.0	XI ^[4]

Richter Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0+	VIII or higher

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So this is how the people started quantifying the earthquake based on the recorded data. You can see this is actually a typical earthquake and death toll and the Richter magnitude estimation and the Mercalli intensity. You can see that the intensity of Tangshan reported for the 250,000 people and then in 2010 it was reported 316,000 people ok. So even though it is a function of the damage but you can see the difference.

So this kind of ambiguity is now can be minimized when you have the quantified way of your seismic signal and which is further used for the getting this one. So you can see the 1 to 1 comparison between the Richter magnitude and typical maximum Mercalli intensity scale you can see how much it is coming ok. So this is the typical comparison of from the past earthquake.

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Other local Magnitudes

Duration Magnitude (Md)

- Analog paper or film recordings have limited dynamic range. These records are often clipped for strong or even medium magnitude local seismic events. This makes magnitude determination from A_{max} impossible. Therefore, alternative magnitude scale such as M_d was developed.
- This scale is based on signal duration. It is almost routinely used in micro earthquake surveys.

Macroseismic Magnitude (Mms)

Macroseismic magnitudes (M_{ms}) are particularly important for analysis and statistical treatment of historical earthquakes. There are three main ways to compute M_{ms} :

So other than Richter there is another magnitude developed which is also called local magnitude. Why it is local magnitude means? You can use generally the seismic record in the regional network will have the P and S wave as a major component ok. So those kinds of local data are been useful for original network data. That is why it is called as a regional magnitude. So the analog paper or film recordings have limited dynamic range.

So this record often clipped for the strong or even medium magnitude local events. It makes magnitude determination from the A_{max} impossible. So when you use a analog paper and all those day what happen due to the paper limitation and all you do not sometime record a highest peak which is happening in the site. So those cases using of those kinds of A_{max} for the local magnitude determination is problem.

So they come up with the alternate magnitude that is called as a MD. So the MD is basically duration magnitude it is based on the signal duration it is almost routinely used in the micro earthquake survey ok. So it is called as a MD. So another one; is used as a macro seismic magnitude. So which is a M and ms are particularly important for the analysis and statistical treatment of the historical earthquake data.

So three are the 3 main ways to compute the MMs are available. But these are all the scale only used at a selected place not universally accepted only the ML magnitude is universally accepted many people used. So now you know that why the Richter intensity or Richter magnitude is

reported. So it has to be told the local magnitude or Richter magnitude. There is no quantification part Richter intensity or intensity in the Richter scalar those are all basically wrong description of the earthquake size.

So here we have seen that when there was a deep and far away earthquake ok so the local earthquake you will get a P and S wave dominant. If there is deep and far away earthquake you will not get P and S wave as a dominant measurement in the same seismic station. So those places basically they need to go for the alternate way of magnitude estimation where the concept of tele-seismic magnitudes, are come into picture ok.

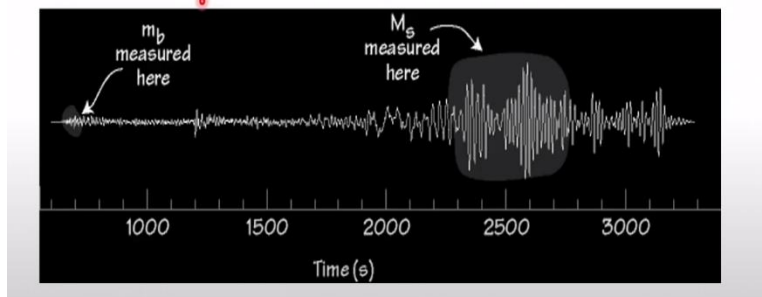
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Teleseismic M_S and m_b

□ The two most common modern magnitude scales are:

□ M_S , Surface-wave magnitude (Rayleigh Wave)

□ m_b , Body-wave magnitude (P-wave)



So there are 2 tele-seismic means the waves are traveling from the very far distance like body wave and a surface wave. So you can see the typical time lap and what was the surface wave arrival. You can see basically the surface wave arrival here see how much it is. So this is your mb. So some places where you will get mb as a predominant, some place you will get Ms as a predominant depends upon your location and where the earthquakes are occurring. That is what you have seen in the wave propagation.

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Surface Wave Magnitude

- Richter's local magnitude does not distinguish between different types of waves.
- At large distances from epicenter, ground motion is dominated by surface waves.
- Gutenberg and Richter (1936) developed a magnitude scale based on the amplitude of Rayleigh waves.
- Surface wave magnitude $M_s = \log_{10}A + 1.66 \log_{10}\Delta + 2$
 - Assumes a 20 sec period

- A = Maximum ground displacement in micrometers
- Δ = Distance of seismograph from the epicenter, in degrees.
- Surface wave magnitude is used for shallow earthquakes

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So the surface magnitude basically which uses a surface wave of the earthquake record. So the Richter local magnitude does not distinguish between the different types of waves. At large distances from the epicenter ground motion dominated by surface waves. The Gutenberg and Richter ok it is basically the student of Richter in 1939 develop a magnitude scale based on the amplitude rally wave. The surface wave $M_s = \log A + 1.66 \log 10 \Delta + 2$ assumes that 20 second period.

A maximum ground displacement in micrometer. Delta is the distance of seismogram from the epicenter in degree. Surface wave magnitude is used for the shallow earthquakes ok. So this is a estimated from the surface wave record of the particular place.

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- It is a measure of the amplitude of LR-waves with a period of 20 seconds, i.e wavelength of about 60 km, which are common for very distant earthquake, e.g where the epicenter is located at more than 2,000 km.
- Used for large earthquake
- Can not be used to characterize deep or relatively small, regional earthquakes
- The relationship between amplitude A, period T, Distance Δ and M_s is given by

$$M_s = \log\left(\frac{A}{T}\right) + 1.66 \log(\Delta) + 3.30$$

- Where Δ is measured in degrees, the ground motion amplitude in microns and the period in seconds
- This equation is applicable for $\Delta > 15$

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So it is measure of the amplitude LR waves basically the rally wave for the 20 seconds wave length is above 60 kilometer which are commonly very distance earthquake and where the epicenter is located more than 2000 kilometer. So used for the larger earthquake cannot be used for characterize deep and relatively small and regional earthquake. The relation between the amplitude A and period T and distance Delta and M_s is given by this relation which can be used to estimate a magnitude of the particular earthquake using the surface wave.

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Body Wave Magnitude

- For deep focus earthquakes, reliable measurement of amplitude of surface waves is difficult.
- Amplitudes of P-waves are not strongly affected by focal depth. Gutenberg (1945) developed a magnitude scale based on the amplitude of the first few cycles of P- waves, which is useful for measuring the size of deep earthquakes.

Body wave magnitude

$$M_b = \log_{10}A - \log_{10}T + 0.01 \Delta + 5.9$$

A = Amplitude of P-waves in micrometers

Δ = Distance of seismograph from the epicenter, in degrees.

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So the next is body wave magnitude. So they say that it is a basically estimated from the using body wave amplitude. So as we have seen that the amplitude of P wave are not strongly affected by the focal depth. The Gutenberg developed a magnitude scale based on the amplitude of the

first few second of P waves which is useful for the measuring the size of deep earthquakes. So the body wave magnitude M_b is equal to this is the function they use so this is the amplitude and delta is the distance seismogram from the epicenter in degrees. And these are all the T and 5.9 as the constant.

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- m_b can measure distant events , e.g. epicentral distances not less than 600 km
- P-waves are not affected by the depth of energy source
- Commonly used in Eastern North America due to deeper earthquakes
- Magnitude m_b is related to the amplitude A and period T of the P waves as follows

$$m_b = \log \frac{A}{T} + \sigma(\Delta)$$

- $\sigma(\Delta)$ is function of the epicenter distance Δ (in degrees)

So using this you can get a m_b can measure distance events epicenter distance are less than 600 kilogram. And the P waves are not affected by the depth of energy source. So commonly used in eastern north America due to deeper earthquake in that region. Magnitude M_b is related to the amplitude of A and period T and P waves as follows. So this is basically the relation between the A and T and delta D. So this will give you the m_b magnitude.

So if you some earthquake if you, estimate see now we studied ML, m_b and then MS. If we estimate all 3 for the same earthquake does it will be similar or different. Obviously it may not be similar as this is consider the wave amplitude depends upon the location of the place so you will get a shadow zone and non-shadow zone and then wave amplitude as a greater or smaller ok. So that is what it will give you. So this has been noticed by the scientist why the scale or not same ok.

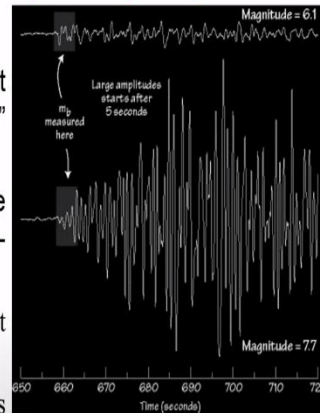
For example the Turkey earthquake MS = 7.8, m_b = 6.3 ok. So then the Taiwan MS = 7.7 and m_b = 6.2. The distance correction factor for amplitude depends on the geology and deep

earthquake do not generate large surface waves. So MS biased low for medium earthquake. Some of the earthquake last longer than the other even though the peak amplitude is not a same.

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Why Don't Magnitude Scales Agree? (cont)

- Magnitude scales *saturate* :
 - This means there is an upper limit to magnitude no matter how "large" the earthquake is
 - For instance, M_s (surface wave magnitude) never gets above 8.2-8.5
- m_b seldom gives values above 6.7 - it "saturates".
- m_b must be measured in the first 5 seconds - that's the rule.



Example: m_b "Saturation"

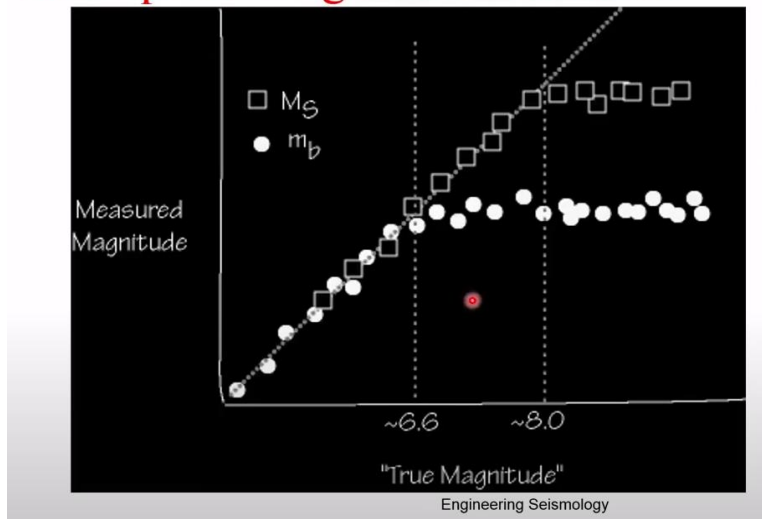
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So this kind of phenomena where the magnitudes are not similar this because of the there is a saturation of the wave. So if you find the magnitude from the saturation this kind of magnitude which does not go beyond some limit is called as magnitude scale saturation. This means that there is a upper limit of the magnitude no matter how large the earthquake is ok if we consider ML, MS, mb kind of measurement.

For the instance MS surface wave magnitude never gets above 8.2. So mb seldom gives value of 6.7 in saturation b must be measure in the first 5 second of the rule. So this is the typical seismogram where you can see basically the mb measure here and then followed by the MS and as well as the surface wave magnitude using this data you can estimate a your this one.

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Earthquake Magnitude Saturation



So if you plot the magnitude versus the measured data. You can see that the m_b saturate at the value of 6.7. Similarly the M_S saturate at a magnitude of 8. So beyond 8 you will get a same M_S irrespective of the side distance and the side condition and wave what you record because that is the problem. So similarly 6.7 also for the same kind of issues we can expect in the magnitude.

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What Causes Saturation?

- The amplitude of seismic waves radiated at a particular period is related to what is happening at the source over distances comparable to their wavelengths.
- If wavelength is long compared to the size of the source, the amplitude of the wave will represent a simple integration of the effect of the earthquake source deformation
- If wavelength is short compared to the size of the source, the amplitude of the wave will reflect details of the rupturing process.

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So this kind of phenomena after some value the magnitude is constant that kind of phenomena is called as a magnitude saturation which is called as magnitude saturation. That means up to some extent the value keep increasing beyond some that particular extent the magnitude remains constant irrespective of your amplitude and time. So, why the magnitude saturation happens? So

the amplitude of the seismic waves radiate at a particular period is related to what happening to the source over a distance comparable to the wavelet.

If, the wavelet is long compared to the size of the source the amplitude of the wave will express simple integration of the effect of the earthquake source deformation. If the wavelength is short and compared to the size of the source the amplitude of the wave will reflect a detail of the rupturing process.

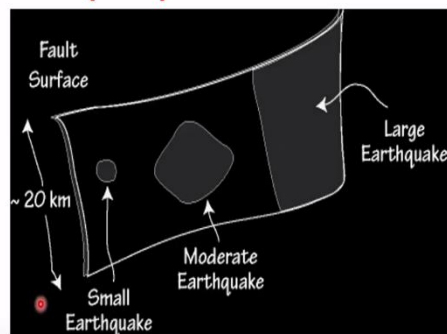
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What Causes Saturation? (cont)

□ The rupture process.

- Small earthquakes rupture **relatively** small areas; therefore the amplitude of short period signals yield good measures of the seismic source.

- Large earthquakes rupture **relatively** large areas and only the longest wavelengths yield good measures of seismic source.



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So these are all the reasons why the saturation is taking place. So in general the small earthquake for rupture relatively small area therefore the amplitude of short period signal need to be good yield a good measurement of the seismic source. So the large earthquake rupture; relatively large area where only the largest wavelength yield a good measures of seismic source. So when you measure a estimate a seismic magnitude you should be aware all this information which will help you to estimate a reliable magnitude for your sight and earthquake that will be so does not vary with respect to the time of the scale.

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Are m_b and M_s still useful?

- YES!
 - Many (most) earthquakes are small enough that saturation does not occur
 - Empirical relations between energy release and m_b and M_s exist
 - The *ratio* of m_b to M_s can indicate whether a given seismogram is from an earthquake or a nuclear explosion (*verification seismology*)
 - M_s used to estimate M_0 { $\log M_0 = 16.1 + 1.5M_s$ (dyne-cm) - or- $\log M_0 = 10.92 + 1.11M_s$ (Nt-m)}

So but still this m_b and M_s are useful yes. Why because most of the earthquake is small enough the saturation does not occur. You have seen that 6.7 for the m_b and 8 for the M_s . So if you have the less than that your magnitude will remain similar there is no kind of saturation or quarantine is required. So the empirical relation between the energy released and m_b and M_s exist. So the most earthquakes are small enough which can be measured in this scale.

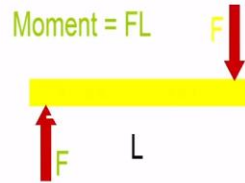
And the empirical relation between m_b and M_s exists. The ratio of m_b to M_s can indicate whether the given seismogram is from an earthquake or nuclear explosion. So you can differentiate this is an artificially created seismic signal such as a blasting or nuclear explosion or this seismogram recorded data. So such kind of things can be arrived when you have the M_s and m_b .

So and also the M_s will be used to estimate a energy from the earthquake because there is direct correlation between the M_s and the M energy in the literature. So these are all the application where m_b and M_s still are useful.

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Is there anything better?

- Yes, the *seismic moment* – M_0
 - Invented in the 1960s to circumvent magnitude limitations
 - Has physical units of energy (Nt-m, dyne-cm)
 - Is the product of three factors that indicate the size of the earthquake:
 - $M_0 = (\text{shear modulus}) \times (\text{rupture area}) \times (\text{slip offset})$



- Two equal & opposite forces = *force couple*
- Size of couple = *moment*
- Numerical value = product of value of one force plus distance between

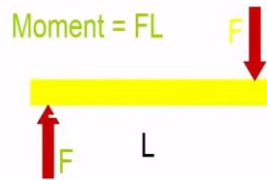
So anything better which can record the earthquake? Yes the scientists are gone through this one and try to update and come up with a new concept of magnitude which is based on the fault moment at a particular place. So the seismic moment which is called as a M_0 so invented in 1960 to circumvent magnitude limitation as a physical unit of energy like in newton dyne centimeter or newton meter. This is a product of 3 factors that indicate size of the earthquake.

So the moment at particular place is equal to the stiffness, and rupture area and slip offset. So basically this is your fault so due to the up and down force. So you can get a moment. So which is the function of your shear modulus, so with this the function of material shear; modulus ok. Then the how much the breaks and ruptures and what is the offset it create or sleep so if you knowing this one can estimate what is the seismic moment M_0 . So if you know the seismic moment you can estimate a moment magnitude ok.

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Seismic moment

- Measures relative strength of shaking locally
- Earthquake magnitude provides measure of size on basis of wave motion
- Peak values used in magnitude determination do not reveal overall power of the source
- Measure of quake size related to leverage of forces (couples) across area of fault slip provides estimate of overall size of the seismic source
- Measured in Newton-metres



- Two equal & opposite forces = *force couple*
- Size of couple = *moment*
- Numerical value = product of value of one force plus distance between

The seismic moment is basically the measure relative length of the shaking locally. The earthquake magnitudes provide measure of size on bias of the wave motion. The peak values used in the magnitude determination do not reveal overall power of the source. The measure of quake size related to leverage forces couples across the fault slip provides estimate overall size of that will be estimated that is called as a FL is called as a seismic moment.

That moment is used to estimate to a magnitude. That magnitude is called as a moment magnitude.

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Moment magnitude

- Moment values are used to determine the Moment magnitude ($M_w = \frac{2}{3} * \text{Log } M_0 - 10.73$ when M_0 is in dyne-cm or $M_w = \frac{2}{3} * \text{Log } M_0 - 6.0$ when M_0 is in Nt-m)
- Moment magnitude provides a measure of the dimensions of the entire slipped fault - may be 100s km in length
- Seismic waves used to estimate M_s - in contrast - have wavelengths of ~100km for moderate to large quakes
- Such a wavelength will sample only part of the entire fault, so M_s becomes 'saturated' at some upper threshold
- Comparison: Loma Prieta (1989) quake
 - $M_s = 7.1$
 - $M_w = 6.9$

So the moment value are used to determine the moment magnitude the $M_w = \frac{2}{3} \log M_0 - 10.73$ and M_0 is dyne for you can see that it is dyne for the dyne centimeter. So if you use some other unit basically you will be getting a different equation. You can see these constants are changing. You can see here and you can see here ok. This is the newton meter that is on the dyne centimeter.

So the moment magnitudes provide measure of the dimension of the entire slip of the fault and may be 100 seconds kilometer length. Seismic wave used to estimate M_s is in contrast have, the wavelength of close to 100 kilometer for the moderate to large earthquake. Such a wavelength will sample only part of the entire fault. So M_s become a saturated and same upper threshold value. So by comparing the Loma Prieta earthquake you can see the M_s is so much, M_w is so much ok.

So this is the difference we can estimate. But to measure the moment you need to know what is the; rupture length of the fault?

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Magnitude Summary

- Magnitude is a measure of ground shaking amplitude.
- More than one magnitude scales are used to study earthquakes.
- All magnitude scales have the same logarithmic form.
- Since different scales use different waves and different period vibrations, they do not always give the same value.

Magnitude	Symbol	Wave	Period
Local (Richter)	ML	S or Surface Wave*	0.8 s
Body-Wave	mb	P	12 s
Surface-Wave	M_s	Rayleigh	20 s
Moment	M_w	Rupture Area, Slip	100's-1000's

Handwritten notes and diagrams in red ink are present on the right side of the slide, including a sketch of a fault plane with arrows indicating slip and some illegible text.

So the magnitude so overall whatever we discussed so we can see that the magnitude is measure up the ground shaking amplitude ok which is the function of basically how much the amplitude the earthquake has been reported like this ok. How much the amplitude is report that amplitude value is your magnitude let say it may be your P or it may be the S or may be the surface wave depends on.

So the more that one magnitude scale are generally used to quantify the earthquake depends upon the development taken place. All the magnitude scales have the same kind of algorithm form. If we observe the equation all of them is the function of log 10 base. So which indicate that one magnitude like 5, 6 is even though number wise it is only 1 increment but if you say earthquake magnitude 5 and 6 ok which is 10 times larger and smaller.

For example the 4 magnitude is actually 100 times smaller than the 6 magnitude and a similarly 10 times larger than the 3 magnitude of 4. So such kind of amplitude log difference has been in that is why it is used to a log 10 base as a magnitude estimation. So since difference scales are used in different way different period of vibration they do not always give a same value which we have seen in the some of the example.

So in summary the local magnitudes develop by a Richter which is indicated by ML which is generally use as S or surface wave. The maximum component of these 3 wave for a period of so much. The body wave indicated by the mb and uses only the P wave and only the period they use was 12 second. The surface Ms and the Rayleigh wave and it is used so much. The moment magnitude Mw rupture area and slip this is a period the data what they are using for a assessing that ok.

So among this magnitude basically the moment magnitude is more reliable way of getting the earthquake measurement.

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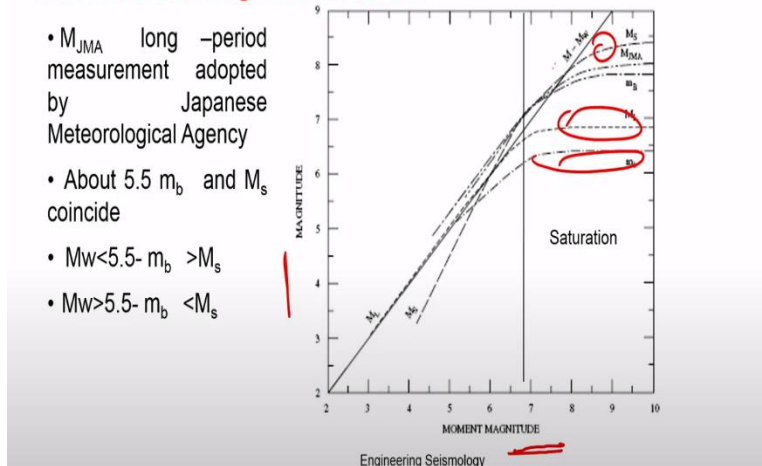
- Earthquake of different size and energy release may have the same magnitude.
- San Francisco (California) & Chile Earthquake
- Both event $M_s = 8.3$
- Fault rupture area in Chile was 3.5 times greater than California
- Different fault rupture lengths correspond to different amounts of energy released: M_w accounts for the extents of fault rupture (Scholz 1990)
- M_w for San Francisco (California) is 8 and for Chile is 9.5
- Magnitude scales do not increase monotonically with earthquake size.

So the earthquake different size and energy releases may have the same earthquake magnitude. So the San Francisco, California and a Chile earthquake has been taken and both event basically measured M_s of 8.3. The fault rupture area of Chile earthquake is actually 3.5 times greater than California earthquake. So, different fault rupture length, correspond to the different amount of energy release.

So the M_w accounts extents of the fault rupture so the M_w for the San Francisco earthquake is actually 8 and Chile is 9.5. The magnitude scales do not increase monotonically with earthquake size ok that was a observation from this you can say. So the M_w is the most reliable scale so as on today they use.

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Relationship between Intensity, moment magnitude and various magnitude scales



So since it was this one there was is a old all the old scales are being converted and there is a conversion for that. So this is the different magnitude moment magnitude this is the different magnitude. You can see here the magnitude of ML up to magnitude of 7 it is no saturation take place. After that there is a saturation. So Mb saturates at a 6.7 you can see here ok. So the Mjb magnitude Japan so long period measurement earthquake and you can see here this is the M - Ms ok this one. And M moment magnitude does not saturate with the earthquake. So the moment magnitude can be find out for the any earthquake.

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- For shallow a earthquake Bolt (1999) suggested using M_D - coda length magnitude for less than 3
- Either M_L or m_b for magnitude between 3 and 7
- M_s for magnitudes between 5 and 7.5
- Richter scale stops increasing at $M_w=7.0$
- Magnitudes m_b and M_s saturate at about 6.5 and 8.5
- M_w does not suffer from saturation problems in the practical range of magnitude of $2 < M_w < 10$
- Intensity - Magnitude Relationship

For the shallow crystal earthquake Bolt suggested that MD and coda length magnitude less than 3 can be used. Shallow crystal either ML or mb for the magnitude between the 3 and 7 will be

fine. So the MS for the magnitude between 5 to 7.5. Richter scale stops increasing at magnitude 7. Magnitude at mb and MS saturate at about 6.5 and 8.5.

So Mw does not suffer from saturation so the problem in the practical range is magnitude 2 to 10 ok. The intensity magnitude relations are available where you can convert intensity as a magnitude, magnitude as a intensity.

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Seismic Energy

Both the magnitude and the seismic moment are related to the amount of energy that is radiated by an earthquake. The relationship is generally expressed as:

$$\text{Log } E = 11.8 + 1.5M_s \text{ or } \text{Log } E = 4.8 + 1.5M_s$$

Energy E in ergs (joules) from the surface wave magnitude M_s . E is not the total "intrinsic" energy of the earthquake, transferred from sources such as gravitational energy or to sinks such as heat energy.

It is only the amount radiated from the earthquake as seismic waves, which ought to be a small fraction of the total energy transferred during the earthquake process.

So those data's are really useful for the your so prediction of the earthquake hazard. So this is about the earthquake magnitude. So during the earthquake magnitude we are also discussed about a energy. So the energy means basically the amount of energy released due to the breaking of the fault. Both the magnitude and the seismic moment are related to the amount of energy that is radiates from the earthquake which you will discuss in the next class.

So today class we have seen about the magnitude and then different type of magnitude scale how you can quantify the magnitude. So we have noticed that all the magnitude is the function of log 10 waves. So that means 1 magnitude is so greater than 10 times ok. So smaller or larger depends upon which number it comes ok. So that is what we have seen so this energy is a function of the wave what you are seeing and how to estimate energy and what are the energy content in the previous earthquakes are reported.

What are the nuclear explosion are taking place and how that energy was there will discuss in the next class. So with this I thank you for watching this video. So we will meet in the next class. Thank you very much.